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ASSESSMENT OF THE POPULATION DYNAMICS OF THE CALIFORNIA SEA LION (*Zalophus californianus*) AT SAN NICOLAS ISLAND, 1984-1985

By

Brent S. Stewart and Pamela K. Yochem

ADMINISTRATIVE REPORT LJ-86-11C

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Assessment of the population dynamics of the California sea
lion (Zalophus californianus) at San Nicolas Island, 1984-1985

by

Brent S. Stewart

and

Pamela K. Yochem

Final Report

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8604 La Jolla Shores Drive
P.O. Box 271
La Jolla, California 92038

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I. INTRODUCTION

Six species of pinnipeds (California sea lion, northern fur seal, Steller sea lion, Guadalupe fur seal, harbor seal, northern elephant seal) inhabit the waters off the California coast. The major rookeries for several of these species in the Southern California Bight (SCB) are at San Miguel and San Nicolas islands. Commercial exploitation in the 18th, 19th and early 20th centuries reduced populations of each species and three species were locally extinct by the late 19th century. With the end of commercial harvest, several species (northern elephant seal, California sea lion, northern fur seal) have increased dramatically in abundance and distribution in the SCB, especially during the past several decades (e.g.; DeLong 1982; DeMaster et al. 1982; Cooper and Stewart 1983; Stewart et al. 1985; Stewart and Yochem 1984, MS). The abundance of Steller sea lions has declined in California waters since the 1930's (e.g., Ainley and Lewis 1974, Pierson et al. 1981, Loughlin et al. 1984) and breeding no longer occurs in the SCB (Stewart 1985). A few Guadalupe fur seals occasionally appear at San Nicolas and San Miguel islands (Stewart 1981, Stewart et al. 1985) but this species still apparently breeds only at Isla de Guadalupe off Baja California.

The major rookeries in the California sea lion's range are at San Miguel (SMI) and San Nicolas (SNI) islands. Data for the largest rookery, at SMI, suggest that the population there is still increasing but that the rate of increase is apparently declining (DeMaster et al. 1982). Pup production of California

sea lions at SNI increased by about 8% from 1980 to 1981 and by slightly more than 15% from 1981 to 1982 (Cooper and Stewart 1982, Stewart and Yochem 1984). Data for years prior to 1970 are problematic but the implications are that population growth at SNI has been consistently high for the last two decades (Cooper and Stewart 1982, Stewart and Yochem MS). The California sea lion population in Mexican waters has also apparently increased significantly since 1966 (LeBoeuf et al. 1983).

This increase in California sea lions has been accompanied by an increase in the intensity of interactions of California sea lions and commercial and sport fisheries (Miller 1981, Miller et al. 1983), especially in central and northern California, where large portions of the southern California population migrate seasonally.

A decline in California sea lion natality at San Nicolas Island of about 42% between 1982 and 1983 (Stewart and Yochem unpubl. data) was apparently density-independent and seems related to the unusual 1982-1983 El Niño event (Stewart 1983) although the causal mechanism in this correlation has not been clearly identified.

We conducted research on California sea lions at San Nicolas Island (Figure 1) from May 1984 through February 1985 to document seasonal abundance, natality and pup mortality, female attendance patterns (i.e., feeding cycles), feeding habits, and interactions of sea lions with commercial fisheries and ocean debris.

II. METHODS

A. Population indices

We monitored natality and pup mortality by censusing the entire population biweekly between 19 May and 11 July 1984. We also made five counts each day of live and dead pups at one study site (223) to examine the precision of biweekly censuses used to estimate pup mortality. The value used to estimate the number of pups present each day was the mean of the five counts for that day. We marked sea lion pups with paint and dye to permit mark-recapture studies of natality and pup mortality. Resight experiments are not reported here, however, because not enough pups could be marked to gain the desired precision in estimates; natality declined again during the summer of 1984 thus making mark-resight studies unfeasible. We censused the entire population approximately monthly during the non-breeding season at times consistent with censuses conducted in previous years (e.g., Stewart and Yochem 1984). Census methods were consistent with those described by Stewart and Yochem (1984). In addition to counts of animals, during each census we recorded the number (by sex and relative age class) of sea lions entangled in fishing gear or debris and those which had scars suggesting previous entanglement. The methods used to document net and debris entanglement are detailed in Stewart and Yochem (1985; see Appendix of this report).

We documented 'pup production' at San Nicolas Island by censusing the entire population on 2 July, by which time most

births had occurred. We define pup production (P) as the number of live pups that are counted on a particular date; in this case, a census timed to coincide with the end of the whelping season. Pup production ($P = B_t - D_t$) is a function of the total number of births (B_t) and deaths (D_t) that occur prior to that census. We measured pup production directly, rather than calculating it by determining B_t and D_t . We use 'natality' to indicate the number of births that occurred during a breeding season; natality (B_t) can be estimated by adding the value for pup production to an estimate, if accurately known, of pre-census mortality (D_t). Pup production is an unambiguous estimate of natality, however, only when the magnitude of pre-census pup mortality is very small. Some authors have assumed that pup production is synonymous with natality without noting the potential bias in using a measured value indiscriminately when examining trends in either index of population abundance.

California sea lion pups are born within a brief time period (late May through early July) but parental care may continue for a year or possibly longer. Premature births appear to be more frequent in California sea lions than in other species of pinnipeds and may occur from January through early May. Pups born in mid to late May are considered to be full term. Pups generally remain on the beaches where they were born through early July but become increasingly mobile during late June and early July and begin entering tide pools and the nearshore surf to play by mid-July. The magnitude of undetected mortality due

to drowning during this period is unknown. Sea lion pups that die on rookeries cannot be marked, in general, without major disturbance to nursing females and pups. The small size of sea lion pups and fast rates of decay (both passive and by gull scavenging) and burial in the sand by wind erosion, prevents detailed monitoring of sea lion pup carcass fate during biweekly censuses. We estimated sea lion pup mortality by recording the numbers of new pup carcasses observed during biweekly censuses between 19 May and 2 July; due to disappearance of carcasses between censuses, these counts are underestimates. The combined total of all censuses was compared with the estimate of pup production obtained at the end of the whelping season (2 July). These estimates of pup mortality are therefore minimal estimates during the whelping season only.

B. Physiological indices

As a basis for examining age-specific survival rates we tagged sea lion pups between 21 and 23 September 1985. Each pup was tagged with two red Dalton Riese cattle ear tags, one tag in the trailing edge of each fore-flipper.

We monitored the feeding cycles of parturient female sea lions by documenting the presence (and duration of absence) of naturally marked and uniquely paint-marked females on a daily basis at site 223. We marked females by throwing eggs filled with hair dye or paint at them or shooting paint pellets at them with a sling shot or CO₂-powered pistol.

We collected (opportunistically, i.e. without disturbance to sea lions) scats and spewing samples from hauling areas approximately once each month. Methods of analysis and results are presented elsewhere (Lowry et al., in prep.).

III. RESULTS AND DISCUSSION

A. Population indices

1. Natality, pup mortality and pup production

a) Site 223

At least five births had occurred in the study area at 223 before we began observations on 24 May. The number of pups increased gradually until about 9 June and then increased rapidly through the end of June; 75% of the season's births occurred between 9 June and 25 June (Table I). We calculated the mean date of birth and standard deviation of the season using the following equations:

$$\text{Mean date of birth} = \frac{\sum fx}{\sum f}$$

$$\text{Standard deviation} = \left(\frac{\sum fx^2 - (\sum fx)^2 / \sum f}{(\sum f) - 1} - 1/12 \right)^{1/2}$$

(with Sheppard's correction)

where,

x = period code (corresponding to periods of seven days
beginning on 16 May and running through 4 July)

and

f = the number of births occurring during each period

The mean date of birth using this method was 18 June with a standard error of 0.06 days and standard deviation of the season of births of 14 days. We also calculated the median date of birth at 223 by probit analysis (Caughley and Caughley 1974, Finney 1952) to allow comparison with the median computed for the entire population (see below). This statistic was found to be 18 June with a standard error of 0.5 days and a standard deviation for the season of 10 days.

Twenty-six (10%) of 254 pups born in the study area died between 23 May and 7 July. The distribution of pup deaths during the season was bimodal with a peak very early in the season and a second, larger, peak around the mean birth date (13-27 June); forty-two percent of the season's mortality occurred between 13 June and 27 June. We determined the age of a pup at death indirectly by the freshness and length of the umbilicus or directly for those pups that had been marked at birth or were with paint-marked females with known parturition dates. Of 21 pups whose ages at death were known, twelve died when less than

one day old (six of these may have been stillborn), seven were two to three days old when they died and two died when five days old. The cause of death was determined for sixteen pups: six were apparently stillborn, three pups drowned, three pups died from starvation resulting from separation from their mothers (apparently due to human disturbance to the site when the pups were less than one day old) and four pups were trampled by or trapped under (and apparently suffocated by) subadult male northern elephant seals that were hauled out, and molting, at the study site throughout the summer.

b) San Nicolas Island

The median birth date for the entire population, determined by probit analysis, was 12 June with a standard deviation of the season of 7 days. Median birth dates among sites in 1984 varied from 12 June (± 6.7 days SD) to 17 June (± 5.0 days SD). By extracting data for 1982 and 1983 from Heath and Francis (1984) we compared median birth dates among years (1982, 1983, 1984) at two sites (232 and 233). A more detailed analysis of all breeding areas at SNI is presented in Stewart and Yochem (MS). We present the results of the analysis for sites 232 and 233 here because of their implications for interpretation of pup weights (most pups that we tagged and weighed were captured at these sites). The median birth dates changed at each site, becoming later each year (232: 1982 - 8 June, 1983 - 12 June, 1984 - 13 June; 233: 1982 - 10 June, 1983 - 11 June, 1984 - 14 June).

Pup production (the number of live pups counted on 2 July) for 1984 was 3631, a slight decrease from that observed in 1983 (Stewart and Yochem, MS). Examinations of spatial changes in pup production at SNI appear in Stewart and Yochem (1984) and Stewart and Yochem (MS). A minimum estimate of pup mortality, based on cumulative dead pups observed, was 3% from 19 May through 2 July 1984. Although mortality estimates based on weekly to biweekly censuses tend to consistently underestimate true mortality (e.g., Heath and Francis 1983, Stewart and Yochem 1984) the observed mortality is consistent with that observed in previous years using the same methods (e.g., Stewart and Yochem 1984, Stewart and Yochem MS). Assuming a mortality rate for the entire island similar to that observed at site 223 (10%), natality at SNI in 1984 would have been approximately 4034. Hypothetical mortality rates of 8% and 15% yield natality estimates of 3925 and 4288 respectively. Since there is no evidence to suggest that pup survival prior to the early July census date has been influenced in a density-dependent manner, the pup production estimate (3631) appears to be the most reliable parameter for examining recent population trends if natality is the parameter of choice (but see Berkson and DeMaster, 1985, for a discussion of biases).

Between 21 and 23 September we tagged (Red series 900-999, A00-A99, B00-B59) 257 sea lion pups at areas 223(56), 232(59), 233(60) and 241(82) (Table II). The ratio of males (120) to females (132) did not differ significantly from unity ($\chi^2 = 0.57$, $p > 0.05$, $df = 1$). We also found no significant deviation from an

equal sex ratio among young pups in the data reported by others (Heath and Francis 1984) for SNI (1982, $\chi^2 = 1.18$, $p > 0.05$; 1983, $\chi^2 = 0.94$, $p > 0.05$). Overall, males were significantly heavier ($t = 4.69$, $p < 0.001$, $df = 250$) than females. However, male and female pups were significantly heavier at site 241 than they were at site 223 (t (males) = 1.68, $p < 0.05$, $df = 60$; t (females) = 1.88, $p < 0.05$, $df = 70$), site 232 (t (males) = 1.69, $p < 0.05$, $df = 60$; t (females) = 1.90, $p < 0.05$, $df = 76$) and site 233 (t (males) = 2.62, $p < 0.01$, $df = 62$; t (females) = 2.69; $p < 0.01$, $df = 72$). The reasons for these differences are not apparent, although differences in the median birth date among sites, human disturbance, and the effects of density may be among them (Stewart and Yochem 1984). Weights of male or female pups did not differ significantly among sites 223, 232, or 233 ($p > 0.10$ in each case).

2. Population censuses

The pattern of seasonal abundance (Table III) of sea lions at SNI in 1984 was similar to that observed in previous years (Stewart and Yochem 1984, Stewart and Yochem MS). The annual peak in sea lion abundance ashore occurred during the breeding season (2 July, approximately two weeks after the median birth-date). Numbers ashore declined through December, remained low through January, increased to a second peak in February and then declined until early May.

B. Physiological indices

Based on a randomized, marked (paint or natural marks) sample of 125 females at site 223, 89 (71%) were parturient, and 28 (22%) were non-parturient, and the reproductive status of eight (6%) females could not be determined. Assuming that all eight of the 'unknown reproductive status' females either did or did not give birth, and that this sample is an unbiased representation of the population (i.e., that there was no spatial bias in the distribution of reproductively mature but non-parturient females), between 71% and 79% of sexually mature females gave birth in 1984.

The weights of pups reported by Heath and Francis (1984) for 1982 and 1983 are not directly comparable with those we obtained in 1984 since the former were collected about 45 days earlier in the season. Boness et al. (1983) present some growth rate data that could be used to extrapolate the 1982 and 1983 weights to yield estimates which could be compared with those from 1984. We are, however, reluctant to undertake such extrapolations at this point since, without further inspection of the original data, it is not clear from the figures presented in Boness et al. (1983) that rates of weight gain do differ significantly, as the authors suggest, between males and females during the period of interest (although weights of males are clearly greater than those of females at similar post partum ages).

After giving birth, females spent an average of eight days (± 1 day) ashore nursing their pups before departing for the

first feeding trip ($n = 24$, range = 6 to 10 days). Of 89 parturient females that were marked, data for 21 females were suitable for examination of the duration of feeding trips. The first feeding trip was approximately two days ($n = 21$, $SD = 1$ day, range = 1 to 3 days) followed by approximately one day ashore ($n = 19$, $SD = 1$ day, range = 1 to 3 days). There appeared to be a slight increase (from two to three days) in the length of feeding trips through the third feeding trip, but the sample sizes were too small to adequately examine trends beyond the fourth feeding trip. The average number of days spent ashore between feeding trips appeared to be consistent at about one day (range = 1 to 3 days) through the fifth feeding cycle. When examining the influences of abiotic or biotic influences on the dynamics of foraging cycles (and therefore nutrient transfer to suckling pups) of parturient females, it appears unlikely that these monitoring techniques (manual monitoring of presence or absence) will reliably detect changes in foraging cycle dynamics unless these changes are very dramatic. Heath and Francis (1984) reported a difference in length of feeding trips in 1982 and 1983. It is difficult to compare the data sets, however, since the trip durations for 1982 and 1983 (Heath and Francis 1983, 1984) are reported in units of greater resolution than those actually measured and sample sizes and details on individual foraging cycles are not given. It is also not clear, without closer inspection of original data, that these differences are actually significant, given the potential biases of the methods

of data collection used (see Stewart 1985, for discussion). Continuous monitoring of individuals fitted with radio-transmitters may be the most reliable method (if not the only method) of testing hypotheses concerning environmental or density-dependent influences on foraging cycle dynamics.

Although anecdotal records (e.g., Rowley 1929, Starks, 1921, Peterson and Bartholomew 1967) and our own qualitative observations indicate that some females may nurse pups for up to or longer than one year, quantitative data are not available to determine the frequency (of individuals or age-specific population averages) at which females give birth. Quantitative data are similarly lacking to determine ages (minimal and average) at sexual maturity or first reproduction. In 1984, however, we did not observe any three-year-olds (tagged, known age) give birth (tagging began at SNI in 1981, Heath and Francis 1983).

Data are still inadequate (primarily because of restricted tagging effort and low resight probabilities) to precisely or even roughly estimate age-specific survival based on tagged sea lion cohorts and it is unlikely that such data will become available given the small numbers of pups tagged each year (100-300, or less than 5 to 8% of pups produced). Since data on age-specific reproductive and mortality rates for California sea lions do not exist and are unlikely to be collected in sufficient quantity to allow precise or accurate measurement of these rates by presently used methods, the application of Leslie Matrix models is inappropriate. Examination of changes in abundance of

populations may, therefore, be restricted to monitoring some index of abundance. Either pup production (pre-census natality less pre-census mortality, estimated via count in early July) or natality (if it can be accurately measured) still appear to be the best indices of abundance for analyzing changes in population abundance. Berkson and DeMaster (1985) have, however, theoretically examined the nature of the relationship of these indices to total population size while exploring the effects of several kinds of density-dependent survival on population trends. If density-dependent, pre- or post- census pup survival may affect the accuracy of predictions of population trends based on pup counts by changing the direction or increasing the magnitude of bias. Although they have not been empirically tested, theoretical arguments (Berkson and DeMaster 1985) suggest that statements about trends in population abundance, based on pup counts, may be most misleading when pre-census survival is density-dependent.

Pre-census survival of California sea lions may be an impractical parameter to measure on a population level. Although it may be possible to detect the effects of increased "density" or population size on pre-census pup survival by qualitatively or quantitatively monitoring mortality, a density-dependent mechanism might not be unambiguously identifiable. For California sea lions, neonatal survival might be influenced directly by crowding on rookeries or indirectly by increased intraspecific competition for limiting food resources among

females during local foraging excursions during the breeding season.

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Table I: Natality and pup mortality of California sea lions
at SNI, site 223, in 1984.

Date	Live ¹ pups	Cumulative dead pups	Date	Live ¹ pups	Cumulative dead pups
8 June	17	11	27 June	178	23
9	20	11	28		23
10		11	29	200	24
11		12	30	202	24
12	40	12	1 July	219	24
13	55	12	2	225	25
14	67	13	3	219	25
15	71	14	4	229	25
16	95	15	5	215	25
17	109	16	6	217	25
18	122	17	7		25
19	135	17	8		25
20	130	19	9	212	26
21	145	19	10	196	26
22	173	19	11	222	26
23	171	19			
24	174	20			
25	199	22			
26	187	23			

¹ The number of live pups reported is the average of five censuses made each day.

Table II. Weights of California sea lion pups tagged at SNI between 21 and 23 September 1984.

Area	Males			Females		
	$\bar{x}$	s	n	$\bar{x}$	s	n
223 ¹	14.9	1.7	29	12.6	2.2	26
232 ²	14.9	2.6	27	12.7	2.2	32
233	14.0	2.3	31	12.2	1.1	28
241 ³	16.2	2.0	33	14.1	2.2	46
Total ⁴	15.0	2.2	120	13.1	2.1	132

1 Excluding one pup of unknown sex (wt = 11.4 kg)

2 Excluding one male of unconfirmed age (wt = 19.8 kg)

3 Excluding two females (wts = 21.6 kg, 19.3 kg) and one male of unconfirmed age (wt = 22.0 kg)

4 Excludes those indicated above.

Table III. Population censuses of sea lions at San Nicolas
Island, 1984-1985.

	<u>Adult Males</u>	<u>Others</u>	<u>Live Pups</u>	<u>SAMS</u>	<u>New Dead Pups</u>	<u>Total</u>
19 May 1984	116	6785	3	233	8	7145
10 June 1984	325	5560	631	398	21	6935
17 June 1984	620	5186	1786	586	21	8199
2 July 1984	995	5059	3631	912	47	10644
15 Sept 1984	0	1683	2332	21	17	4205
21 Dec 1984	0	1414	2162	59	-	3635
29 Dec 1984	2	2611	1884	62	-	4559
5 Jan 1985	7	2447	1678	68	-	4200
13 Jan 1985	17	2487	1819	117	-	4440
10 Feb 1985	41	5099	-	1229	-	6369
24 Feb 1985	41	5708	-	1393	-	7142
20 Apr 1985	10	3688	-	106	4	3808

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Appendix: Entanglement of pinnipeds in net and line fragments and other debris in the Southern California Bight. Stewart, B. S. and P. K. Yochem. 1985. Proceedings of the workshop on the Fate and Impact of Marine Debris. Honolulu, Hawaii. 26-29 November, 1984.

ENTANGLEMENT OF PINNIPEDS IN NET AND LINE FRAGMENTS AND OTHER DEBRIS IN THE SOUTHERN CALIFORNIA BIGHT

Brent S. Stewart and Pamela K. Yochem
Hubbs Marine Research Institute
San Diego, CA 92109

ABSTRACT

We documented cases of pinnipeds with various kinds of debris entangling them at San Nicolas and San Miguel Islands, California, from 1978 through 1982. In 1983 and 1984 we conducted systematic surveys to document the frequency of entanglement of northern elephant seal, Mirounga angustirostris; California sea lion, Zalophus californianus; and harbor seal, Phoca vitulina richardsi, in marine debris. Approximately 0.08% of the animals in each population had materials encircling their necks or torsos while another 0.06 to 0.10% had scars indicating previous encounters with entangling materials. Encounter with marine debris could be confirmed as the cause of entanglement in only a few cases; trawl net fragments and plastic packing bands were the entangling debris in these instances. Most entanglements appeared to be related to interactions of pinnipeds with operational commercial and perhaps sports fisheries rather than with debris. Although some pinnipeds in southern California waters are apparently being entangled by marine debris, the magnitude of debris-related mortality remains unknown. Assessment of the impact of marine debris on pinniped population will require 1) that entanglement during fishing operations be distinguished from encounter and entanglement with discarded or lost gear fragments and other debris and 2) determination of mortality rates of debris-entangled pinnipeds.

INTRODUCTION

The interactions between marine mammals and commercial or sport fisheries that result in injury to or death of animals have been grossly divided into two types. "Incidental take" refers to mortality of marine mammals that become tangled or trapped in operational fishing gear and either drown or are shot or clubbed before they are disentangled or cut free from the gear. It may also refer to shooting of animals by fisherman at sea or on rookeries or collision of vessels (or their propellers) with marine mammals. "Entanglement" has been used by some authors to describe the phenomenon of animals becoming entrapped in discarded net fragments (i.e., "passive fishing gear") and other debris as well as in active

fishing gear. Fowler (1982), however, reserved the term "entanglement" to refer to marine mammals being wrapped or caught in debris (including fishing gear) that had been lost or discarded at sea. Since marine mammals caught in actively fished gear may be cut free, leaving some net or line fragments attached to them, it is often difficult to confirm that certain kinds of entangling material observed on animals were actually debris when the animals encountered them. Here we use the terms "entangled" and "entanglement" to describe all cases of man-made items encircling the bodies of pinnipeds observed during our surveys. We do, however, consider the possibility that pinnipeds may have encountered these items while interacting with active fishing gear rather than debris at sea.

The extent of interactions of pinnipeds with commercial and sports fisheries has received much attention recently (e.g., Northwest and Alaska Fisheries Center 1980; Anonymous 1981; Everitt et al. 1981; DeMaster et al. 1982; Fowler 1982; Miller et al. 1983; Swartzman and Haar 1983; Metleff and Rosenberg 1984) primarily because these interactions result in damage to fishing gear and loss of marketable fish. The effects of pinniped mortality from fishery interactions (including entanglement in gear and gear debris) on the status and trends of pinniped population have, however, received limited attention. Anecdotal observations have been reported of pinnipeds with various kinds of man-made items encircling their necks or torsos; tissue damage has been observed in many cases. Few cases, however, have been observed or reported of pinnipeds that have died as a result of entanglement in debris. The effects of pinniped entanglement in marine debris on population trends have therefore been difficult to assess. Interpretations of the potential effects have often been limited by a lack of information on the proportion of a population that becomes entangled in debris, the sex and age structure of those entangled animals, and the fate of entangled animals.

Fowler (1982) summarized systematic observations on the occurrence of net fragments and other debris entangling northern fur seal, Callorhinus ursinus, at the Pribilof Islands since the mid-1960's and examined the potential effects of mortality resulting from entanglement on population trends. Entanglement of other species of pinnipeds has been noted by several authors (e.g., Kenyon 1981; Bonner 1982; Allen and Huber 1983; Canil and Canil 1983; Henderson 1983; Huber et al. 1983) but most accounts are anecdotal; the magnitude of entanglement by various types of marine debris and the extent of mortality resulting from entanglement are unknown.

Since 1978, we have made ground censuses of pinniped populations at San Nicolas and San Miguel Islands at intervals varying from weekly to monthly (e.g., Stewart 1980, 1981; Stewart and Yochem 1984). Before 1983 we noted any animals observed on these censuses that were entangled in debris. We recorded the types of debris entangling animals as well as that found on beaches. The number of entangled animals observed during that period was low but our surveys of entangled animals were not systematic and therefore the data are not useful in assessing the frequency of entanglement in each population.

In 1983 we began systematic surveys of northern elephant seal, Mirounga angustirostris, California sea lion, Zalophus californianus, and harbor seal, Phoca vitulina richardsi, at San Nicolas Island (SNI) and of

northern elephant seal and harbor seal at San Miguel Island (SMI) to document the frequency of pinniped entanglement in various kinds of debris. We also continued to document debris (type, amount, size) that had washed ashore on these islands. Surveys for entangled animals were conducted simultaneously with, but independently of, population censuses. We chose small groups of animals in each census area (see Stewart and Yochem 1984) and surveyed them using binoculars or a spotting scope. We also used a Celestron C-90 spotting scope to photo-document entangled animals. At SNI, where most of the work was concentrated, pinniped rookeries and hauling areas extend along approximately 13 km of coastline on the south side of the island. The populations are naturally subdivided into smaller groups (census areas) along this area by topography. In each census area we surveyed small groups of seals and sea lions and recorded the number examined, the number entangled, and the number scarred from prior entanglement. We classified each animal examined by age and sex; only those animals whose entire bodies could be seen clearly were included in the "entanglement survey."

RESULTS AND DISCUSSION

Although our surveys were often more frequent, we used only a single survey per month (usually mid-month) to determine the magnitude of entanglement for each species (Tables 1, 2, and 3). We assume that each monthly sample is independent of other monthly samples and therefore that each sample is of a unique number of animals. Any tendency for entangled animals to spend more time hauled out than nonentangled animals may bias the analysis and result in inflated estimates of entanglement. The season of the sample may also affect estimated entanglement rates if entangled animals remain at the rookeries longer than do nonentangled animals of similar age and sex classes that may migrate and be entirely absent or in low abundance at certain seasons. Combined estimates of entanglement rates then may be more accurate if based on seasonal samples taken throughout the year. Combining all sampling periods, we examined 13,175 sea lions, 11,054 elephant seals, and 1,877 harbor seals. Approximately 0.08% of sea lions, 0.08% of elephant seals, and 0.05% of harbor seals had synthetic items encircling their bodies and an additional 0.10% of sea lions, 0.06% of elephant seals, and 0.05% of harbor seals had scars suggesting previous entanglement with debris or encounters with actively fished nets or longlines. We were generally unable to discriminate among polypropylene, polyethylene, or other synthetic multifilament synthetic materials such as "poly."

Of the 11 sea lions observed entangled, 2 had packing bands (1 plastic, 1 rubber) around their necks, and 5 were entangled in monofilament gill net fragments; 1 yearling sea lion with a gill net fragment tightly constricting its neck was later observed dead. Four sea lions had tangled lengths of monofilament fishing line caught around their necks (Table 4); we did not observe hooks attached to any of the fishing line. Thirteen sea lions had scars encircling their necks; the scar patterns were suggestive of thin monofilament, either fishing line or gill net, rather than of the thicker multifilament materials or more robust packing bands. Therefore, of 24 sea lion "entanglements" observed, 13 (54%) were of animals that had lost the entangling material. In 22 of these 24 "entanglements" it is likely that the sea lions acquired the entangling material or scars during interactions with commercial or sport fisheries. Two of the "entangled" sea lions had apparently been entangled in debris (packing bands).

Table 1.--Incidence of entanglement of California sea lions at San Nicolas Island.

Date	Adult males	Subadult males	Females and juveniles	Yearlings	Pups	Total
Dec. 1983						
Sampled	1	26	721	20	468	1,237
Entangled	0	0	0	0	0	0
Scars	0	0	1	0	0	1
Jan. 1984						
Sampled	0	46	596	83	510	1,235
Entangled	0	0	0	0	0	0
Scars	0	1	0	0	0	1
Feb. 1984						
Sampled	0	115	843	18	518	1,494
Entangled	0	0	0	2	0	2
Scars	0	0	1	0	0	1
Mar. 1984						
Sampled	0	35	389	46	425	895
Entangled	0	0	0	0	1	1
Scars	0	0	0	0	0	0
Apr. 1984						
Sampled	0	0	315	32	218	565
Entangled	0	0	1	0	0	1
Scars	0	0	1	0	0	1
May 1984						
Sampled	16	31	489	62	0	598
Entangled	0	0	0	1	0	1
Scars	0	0	1	0	0	1
June 1984						
Sampled	100	86	626	120	35	967
Entangled	0	1	0	1	0	2
Scars	1	1	0	0	0	2
July 1984						
Sampled	228	355	607	96	340	1,626
Entangled	0	0	0	2	0	2
Scars	1	4	1	0	0	6
Sept. 1984						
Sampled	0	31	1,683	210	501	2,425
Entangled	0	0	1	1	0	2
Scars	0	0	0	0	0	0
Oct. 1984						
Sampled	0	0	234	31	457	722
Entangled	0	0	0	0	0	0
Scars	0	0	0	0	0	0
Nov. 1984						
Sampled	0	78	703	53	577	1,411
Entangled	0	0	0	0	0	0
Scars	0	0	0	0	0	0
Total						
Sampled	345	803	7,206	771	4,049	13,175
Entangled	0(0%)	1(0.012%)	2(0.03%)	7(0.91%)	1(0.02%)	11(0.08%)
Scars	2(0.58%)	6(0.75%)	5(0.07%)	0(0%)	0(0%)	13(0.10%)

Table 2.--Incidence of entanglement of northern elephant seals at San Nicolas and San Miguel Islands.

Date	Adult males	Subadult males	Females	Juveniles	Yearling	Pups	Total
San Nicolas Island							
Dec. 1983							
Sampled	43	51	32	35	115	10	286
Entangled	0	2	0	0	0	0	0
Scars	0	0	1	0	0	0	1
Jan. 1984							
Sampled	111	48	486	0	9	415	1,069
Entangled	0	1	0	0	0	0	1
Scars	0	0	0	0	0	0	0
Feb. 1984							
Sampled	120	56	210	0	4	316	706
Entangled	0	0	0	0	0	0	0
Scars	0	0	0	0	0	0	0
Mar. 1984							
Sampled	18	22	30	0	0	315	385
Entangled	0	0	0	0	0	0	0
Scars	0	0	0	0	0	0	0
Apr. 1984							
Sampled	0	0	310	315	18	65	708
Entangled	0	0	0	1	0	0	1
Scars	0	0	0	0	0	0	0
May 1984							
Sampled	0	0	0	249	75	0	324
Entangled	0	0	0	0	0	0	0
Scars	0	0	0	1	0	0	1
June 1984							
Sampled	0	42	268	26	0	0	336
Entangled	0	0	0	0	0	0	0
Scars	0	0	0	0	0	0	0
July 1984							
Sampled	24	43	15	10	0	0	92
Entangled	0	0	0	0	0	0	0
Scars	0	0	0	0	0	0	0
Sept. 1984							
Sampled	1	0	0	266	67	35	369
Entangled	0	0	0	0	1	0	1
Scars	0	0	0	0	0	0	0
Oct. 1984							
Sampled	0	8	15	80	15	221	339
Entangled	0	0	0	0	0	0	0
Scars	0	1	0	0	0	0	1
Nov. 1984							
Sampled	5	25	45	178	15	181	449
Entangled	0	0	0	1	0	1	2
Scars	0	0	1	0	0	0	1
San Miguel Island							
Jan. 1984							
Sampled	385	315	975	0	128	1,268	3,071
Entangled	0	0	2	0	0	0	2
Scars	0	0	0	0	0	0	0
Feb. 1984							
Sampled	312	265	865	0	65	1,413	2,920
Entangled	0	0	0	0	1	0	1
Scars	0	1	1	0	0	0	2
Total							
Sampled	1,019	875	3,251	1,159	511	4,239	11,054
Entangled	0(0%)	3(0.34%)	2(0.06%)	2(0.17%)	2(0.39%)	1(0.02%)	10(0.09%)
Scars	0(0%)	3(0.34%)	3(0.09%)	1(0.09%)	0(0%)	0(0%)	7(0.06%)

Table 3.--Incidence of entanglement of harbor seals at
San Nicolas and San Miguel Islands.

Date	San Nicolas Island			San Miguel Island		
	Adults and juveniles	Pups	Total	Adults and juveniles	Pups	Total
Dec. 1983						
Sampled	72		72			
Entangled	0		0			
Scars	0		0			
Jan. 1984						
Sampled	65		65	165		165
Entangled	0		0	0		0
Scars	0		0	0		0
Feb. 1984						
Sampled	146		146	315		315
Entangled	0		0	1		1
Scars	0		0	0		0
Mar. 1984						
Sampled	168	14	182			
Entangled	0	0	0			
Scars	1	0	1			
Apr. 1984						
Sampled	210	18	228			
Entangled	0	0	0			
Scars	0	0	0			
May 1984						
Sampled	98	4	102			
Entangled	0	0	0			
Scars	0	0	0			
June 1984						
Sampled	235	19	254			
Entangled	0	0	0			
Scars	0	0	0			
July 1984						
Sampled	115	10	125			
Entangled	0	0	0			
Scars	0	0	0			
Sept. 1984						
Sampled	71	3	74			
Entangled	0	0	0			
Scars	0	0	0			
Oct. 1984						
Sampled	86	0	86			
Entangled	0	0	0			
Scars	0	0	0			
Nov. 1984						
Sampled	63	0	63			
Entangled	0	0	0			
Scars	0	0	0			
Total						
Sampled	1,809	68	1,877			
Entangled	1(0.06%)	0	1(0.05%)			
Scars	1(0.06%)	0	1(0.05%)			

Table 4.--Types of synthetic items observed entangling (E) pinnipeds or believed to have caused scars (S) observed on pinnipeds.

	Monofilament				Polypropylene trawl net		Packing bands		Total	
	Line		Gill net		E	S	E	S	E	S
	E	S	E	S						
Sea lions										
Adult males		2								2
Subadult										
Males		6	1						1	6
Females		3								3
Juveniles	2	2							2	2
Yearlings	2		13				2		7	0
Pups		1							1	0
Total	4	13	5				2		11	13
Elephant seals										
Adult males										0
Subadult										
Males	2	3							2	3
Females	1	3					1		2	3
Juveniles	1	1			1				2	1
Yearlings					2				2	0
Pups	1								1	0
Total	5	7			3		1		9	7
Harbor seals										
Adults	1									1
Juveniles							1		1	
Pups										
Total		1					1		1	1

¹One of these found dead 5 days after first seen entangled.

Of nine elephant seals observed entangled, four had monofilament fishing line encircling their necks (no hooks attached), one had monofilament encircling its torso, three were entangled in "poly" trawl net fragments, and one seal had a plastic packing band around its neck (Table 4). Seven other elephant seals had scars encircling their necks which appeared to have been caused by monofilament line or gill net. Therefore, of 16 elephant seal "entanglements," 7 (44%) were instances where seals had been entangled by materials (probably monofilament line or gill net from active fishing gear) but had lost the material, presumably when it became brittle and broke loose. Four (25%) of the elephant seals showing evidence of entanglement were apparently victims of debris (three entangled by trawl net fragments, one entangled by a packing band).

One harbor seal (adult) was observed with a thin scar around its neck (apparently from previous entanglement with monofilament) and one juvenile was observed with a plastic packing band encircling its neck.

Our observations suggest that many pinnipeds may be freed from materials entangling them, primarily monofilament fragments (gill net or longline). Trawl net fragments and packing bands may be lost less easily since we have seen no animals with scars suggesting that they had been previously entangled with these kinds of debris. This may suggest that animals that become entangled in trawl net fragments or packing bands have greater mortality rates than those entangled by monofilament fragments or that entanglement rates of seals and sea lions in monofilament (operational and debris) are higher than those for other debris. However, the data are not adequate to test either of these hypotheses. The only entangled animal that we observed dead (a sea lion yearling) was entangled in a monofilament gill net fragment.

We observed and collected samples of debris, representative of each type observed entangling animals, on beaches at San Nicolas and San Miguel Islands (Table 5). In addition, we found other types of debris in small amounts. The most common type of debris found was "poly" line fragments of various lengths (Table 5). Although these fragments, when tangled, are capable of entangling pinnipeds, we did not observe any animals entangled in "poly" line.

Because systematic surveys of pinniped entanglement with marine debris in the Southern California Bight have not previously been reported, our data can serve only as a baseline for comparison with data collected with similar methods in the future. However, when considering the impact of "marine debris" on pinniped populations, care should be taken when considering whether all cases of "entanglement" are debris-related. Packing bands, other nonfishing gear items, and trawl net fragments encircling the bodies of pinnipeds are most likely encountered as debris. Entanglement in monofilament line and small gill net fragments probably occurs most often when animals are caught in actively fished gill net or become tangled in actively fished longline gear. If this is true, then most (86%) of the pinnipeds observed (in the Southern California Bight) that showed evidence of entanglement probably encountered the entangling material while interacting with actively fished commercial fishing gear (apparently monofilament gill nets) rather than as debris. The marine debris that appear to be entangling small numbers of pinnipeds in the Southern California Bight are trawl net fragments (with holes in the mesh) and plastic packing bands. Juveniles appear to be the most likely to become entangled in debris and this may be related to their greater degree of curiosity or playfulness or perhaps to their higher rate of encounter with debris sources. California sea lions and northern elephant seals are migratory and (especially young animals) disperse over long distances (primarily northward from rookeries) during the first several years of life.

Assessment and interpretation of the population effects (in the Southern California Bight) of mortality due to entanglement with marine debris require data on 1) the origin, movement, and fate of various kinds of debris with respect to the dynamics of seasonal sex and age class distributions of pinnipeds in eastern North Pacific waters (i.e., rate of

Table 5.--Weights and dimensions of debris found on beaches (B) or removed (E) from entangled dead or live pinnipeds at San Nicolas and San Miguel Islands.

Types of debris	Sample							
	1	2	3	4	5	6	7	8
Monofilament lines								
Weight (g)	227/E	20/E	12/E					
Diameter (cm)	0.15	0.12	0.05					
Monofilament gill net								
Weight (g)	70/E							
Diameter (cm)	0.10							
Mesh size (cm)	20.3							
Dimensions (cm)	61x55							
"Poly" net								
Weight (g)	100/B	500/E	100/B	100/B				
Diameter (cm)	0.35	0.35	0.35	0.35				
Mesh size (cm)	10.2	26.7	26.7	13.1				
Dimensions (cm)	30x15	91x92	46x58	63x39				
"Poly" line ¹								
Weight (g)	43.5/B	1,174/B	78.4B	883/B	639/B	340/B	144/B	48/B
Diameter (cm)	0.8	0.7	0.5	0.9	0.33	0.12	0.8	1.1
"Poly" gill or trammel net								
Weight (g)	86/B	93/B						
Diameter (cm)	0.2	0.2						
Mesh size (cm)	25.4	25.4						
Dimensions (cm)	91x107	111x106						
Lobster pot floats with line								
Weights (g)	676.4/B	812/B	642/B	1,026/B	467/B	1,121/B	787/B	
Buoys with line								
Weights (g)	2,300/B	1,436/B	3,000/B	3,100/B	1,011/B	1,232/B		
Buoys without line								
Weights (g)	1,856/B	1,204/B	665/B	531/B	564/B			
Other								
Weight (g)	227/E	(SKYRO/Fig. 3)						
Dimensions (cm)								

¹ Representative sample selected from a total of 28 samples collected from beaches.

encounter with debris capable of entanglement) and 2) on the probability of mortality of pinnipeds once they become entangled. Proper interpretation of entanglement and the role of debris in entanglement also require that entanglement resulting from encounters with active fishing gear be distinguished from that resulting from encounters with debris.

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